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AID Report P-63-118 4 November 1963

424026

TRACKING OF MISSILES AND SPACE VEHICLES

Compilation of Abstracts

AID Work Assignment No. 12

(Report No. 20 in this series)

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FOREWORD

This is the twentieth report in a series reviewing Soviet developments in tracking missiles and space vehicles. It is based on source materials received at the Aerospace Information Division from January 1963 through May 1963. Information not directly related to the assigned subject has been included because of its broad implications for study in this field.

Topics covered in this series are:

I. Electromagnetic problems
II. Ion clounds and ionosphere perturbations
III. Reflections of radio waves from the moon, sun, planets or artificial satellites
IV. The Luxemburg effect
V. Radio astronomy
VI. Effect of a plasma cloud on space vehicle antennas
VII. Effect of propagation on arctic communication
VIII. VLF propagation phenomena as related to tracking

Materials in this report deal with topics II and V.

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TRACKING OF MISSILES AND SPACE VEHICLES

TOPIC II. ION CLOUDS AND IONOSPHERE PERTURBATIONS

1) Alikhanov, S. G., A. V. Komin, G. G. Podlesnyy, and G. L. Khorasanov. Investigation of plasma diffusion in a magnetic field. Zhurnal tekhnicheskoy fiziki, v. 32, no. 10, Oct 1962, 1205-1211.

Plasma produced by passing pulses from a magnetron oscillator (200 kw, f = 2700 Mc, prf = 16 to 64 cps, and pulse width = 1 to 4 μsec) through helium in a tube placed in a cylindrical cavity (Q = 5000 to 10,000) has been studied to obtain data on the diffusion of a disintegrating plasma in a magnetic field. The following observations were made: 1) The value of the He^+ diffusion coefficient in the absence of a magnetic field was found to be 540 ($cm^2 \cdot mm$ Hg)/sec. 2) Curves of plasma decay time plotted against magnetic field intensity at He pressures of $2.5 \cdot 10^{-2}$ to $2 \cdot 10^{-1}$ mm Hg indicate a monotonic increase in plasma life with an increase in magnetic field intensity. It is suggested that diffusion across the magnetic field is caused by collisions of charged particles with the neutral gas. The study was made at the Physicotechnical Institute of the Georgian Academy of Sciences.

2) Al'pert, Ya. L., V. B. Belyanskiy, and A. F. Kutyakov. Equipment for coherent radio recording of Doppler-shift differences of waves radiated from "Kosmos" satellites. Geomagnetizm i aeronomiya, v. 3, no. 1, Jan-Feb 1963, 157-170.

Measurements were made of differences in the Doppler shift of coherent radio waves transmitted by the "Kosmos-I" and "Kosmos-II" satellites. A highly accurate method of measuring the gradient of electron concentration and of the refraction angle of radio waves along the satellite orbits was developed by Ya. L. Al'pert. The measuring setup consisted of a coherent multichannel radio receiving system and a special device for recording the phase difference. A special feature of the measuring setup consisted in a multiple frequency conversion and a large general amplification factor. The receiver displayed a great degree of stability during the recordings and high accuracy in determining the phase difference. Simultaneously

with measurements of the Doppler shift, the recording of amplitudes of all received waves was carried out with the help of separate receivers and recording devices with different recorder speeds (from 0.5 mm/sec to 1 m/sec). When necessary, measurements of field strength could also be made. The minimum distance of the recording system from the satellite was 750 km. Vertical receiving antennas were used.

3) Al'pert, Ya. L., V. B. Belyanskiy, and N. A. Mityakov. Radio investigation of ionosphere structure at coherent frequencies by means of "Kosmos" satellites. (Preliminary results). Geomagnetizm i aeronomiya, v. 3, no. 1, Jan-Feb 1963, 10-24.

A preliminary analysis is given of measurements of the Doppler-shift differences of waves emitted coherently from the transmitting satellites of the "Kosmos" series. "Mayak" coherent transmitters with frequencies of 20.005 and 90.0225 Mc were used aboard Kosmos-I and Kosmos-II. Observations were made during March and April 1962, simultaneously at several points, some of which were separated by more than 1000 km. Data obtained from these measurements disclose details of the structure and reveal certain new properties of the ionosphere. New data were obtained on the gradient of large-scale horizontal inhomogeneities of electron concentration N along the satellite orbit S. The dimensions of these inhomogeneities are from 100 to 500 km and the gradients of electron concentration $\Delta N/\Delta S$ is nearly equal to 1000 to 5000 electrons/cm^3/km. The space modulation of the difference of Doppler shifts made possible the study of spectra of inhomogeneities from 1 to more than 300 km in length. The study of these spectra may lead to the determination of the mechanisms stimulating the formation of inhomogeneities in the ionosphere. A new maximum in one spectrum was found at $\rho_0 = 100$ to 130 km, and the existence of a maximum determined earlier at $\rho_0 = 2$ to 6 km was confirmed. The refraction angle $\delta\varphi$ of radio waves in the ionosphere changed sharply with the passing of the satellite from point to point. The maximum value of $\delta\varphi$ was found to be 3 to 4°. The $\delta\varphi$ decreases or increases inversely with N. Where N is almost constant changes in $\delta\varphi$ are very small.

4) Anisimov, A. I., N. I. Vinogradov, V. Ye. Golant, and B. P. Konstantinov. Investigation of the diffusion of the charged particles of a dense plasma in a magnetic field. Zhurnal tekhnicheskoy fiziki, v. 32, no. 10, Oct 1962, 1197-1204.

The decay of a helium plasma both in the presence and absence of a magnetic field has been investigated at pressures of 0.02 to 0.2 mm Hg and electron densities of $5 \cdot 10^{11}$ to

10^{13} electrons/cm^3 for the purpose of elucidating the problem of plasma diffusion. A gas-discharge chamber in the form of a cylindrical glass tube was used in the experiments. Electrode-discharge pulses with a duration of 20 μsec and current of up to 500 amp created the plasma. A quasi-stationary magnetic field of up to 3000 oe was employed. A special microwave system was utilized to measure phases of the reflected waves at 9400, 15,000, and 27,000 Mc and of waves propagated through the plasma at 9400 and 16,600 Mc. At 9400 Mc and a higher-than-critical electron density, signals reflected from the side of the chamber opposite the emitter, i. e., signals which had passed through the plasma twice, were registered. Interpretation of the electron distribution curves in the absence of a magnetic field leads to the conclusion that they are described by a Bessel function of the zero order. The plasma-decay time constant was determined. It was found that in a magnetic field up to 1000 oe the diffusion speed of particles across this field can be determined by a known expression for the coefficient of diffusion. At magnetic fields higher than 1000 oe it is difficult to make an accurate determination of charged-particle diffusion, since the latter is masked by processes involving the removal of electrons. With a field of up to 3000 oe the value of the diffusion coefficient does not exceed that obtained at 1000 oe. The authors are associated with the Physicotechnical Institute imeni A. F. Ioffe, Academy of Sciences USSR.

5) Bulatov, N. D., and Ye. I. Khristova. Rapidly changing processes in the ionosphere. Radiotekhnika, v. 17, no. 12, Dec 1962, 28-32.

Results of ionospheric observations conducted in 1957-1958 with continuous photographic recording are given. Variations in the height of the F_2, F_1, and E layers, as well as in critical frequencies, were recorded for intervals of up to 5c hr. In detailed tests on the h'F_2 layer it was observed that the effect of layer altitude fluctuations was greatest on short-range transmissions of 200 to 300 km. Sensitivity to these fluctuations was particularly acute for phase-modulated waves. Data for 30-Mc transmission showed that for a path length of 3000 miles the rate of phase variation did not exceed 0.04°/msec during 90% of observation time, while for a shorter path the momentary spurious phase modulation was much greater. Rapid jumps in altitude, and, consequently, in phase also occurred at the moment of propagation transition from one layer to another. These jumps were observed during the morning and evening hours for the regular E, F_1, and F_2 layers and during the appearance of the sporadic E layer. It was found that during periods of magnetic ionospheric perturbations the velocity of variations in the altitude of the h'F_2 layer was two to three times greater than during periods of quiet.

6) Chepura, V. F., B. L. Kashcheyev, and B. G. Bondar'. Investigation of the directional properties of microwave radio-signal scattering by meteor trails. Elektrosvyaz', v. 16, no. 11, Nov 1962, 3-10.

In an experimental study of microwave forward scatter by meteor ionization trails, two identical transmitters were used, one stationary, operating at 47,973 kc, and the other movable, located on an automobile and operating at 47,993 kc. Their master oscillators were crystal-stabilized and thermostatically controlled; their pulse duration was 5 msec with a repetition rate of 100 cps and a pulse power of 1 kw. The receiving point was located about 900 km from the stationary transmitter. The movable transmitter operated at 34 points located along six routes; the stationary one was located at the point of their intersection. The distance between the transmitters varied from 11 to 320 km. In evaluating meteor trail scatter the coincidence coefficient M and correlation factor K were employed. The latter takes into account coinciding signals which might appear as a result of scattering by two simultaneously existing ionization trails. Signals scattered from nonsaturated and saturated trails were recorded separately; the latter fluctuated strongly. The K and M for saturated and nonsaturated trails, as well as the factor combining K and M for both conditions were found not to vary appreciably from their mean values. A family of curves plotted for isovalues of K and M versus distance from the fixed transmitter showed close agreement with results of Villard et al. (Journal of Geophysical Research, no. 2, 1956, 61). With increasing distance between transmitters, K for nonsaturated trails decreased smoothly down to an order of thousandths. The most rapid changes of K with distance occurred on a course perpendicular to the line between the stationary transmitter and receiver, while along this line the variations of K were much slower.

7) Fligel', D. S. Properties of refraction and attenuation coefficients and of the transmission coefficient of the ionosphere at low and ultralow frequencies. Geomagnetizm i aeronomiya, v. 2, no. 5, Sep-Oct 1962, 886-903.

Results of an investigation of radio wave penetration through the ionosphere in the frequency range 1 to 10^6 cps are reported by the Institute of Terrestrial Magnetism and Radio Wave Propagation, Academy of Sciences USSR. A case of a quasi-neutral medium consisting of electrons, ions, and neutral particles was analyzed. Formulas for the refractive index n and attenuation $\varkappa$ were derived and used to compute n and $\varkappa$ for altitudes of 60 to 3000 km. On the basis of the data obtained the values of transmission coefficient S and the average phase velocity ratio v/c were also computed.

These data demonstrated that an extraordinary wave propagates satisfactorily along the field in the ionospheric plasma in daytime in the frequency range 10^2 to 3×10^3 cps and at night in the range 50 to 2×10^4 cps. Data on ordinary waves are not reported because of their complete attenuation in the ionosphere at $\theta = 0°$, which is the angle formed by the wave vector and the earth's magnetic field. A case for plasma consisting of electrons and ions only was considered and the data obtained were compared with those obtained in the first case. As a result of the study the following facts were established. The variations of n, $\varkappa$, and S with θ showed that up to $\theta = 60°$, n, $\varkappa$, and S change at a slow rate. A faster change is observed in the angular range from 60° to 90°.

8) Golant, V. Ye. Investigation of plasma decay in a magnetic field. Zhurnal tekhnicheskoy fiziki, v. 32, no. 11, Nov 1962, 1313-1323.

Some results are presented of an investigation of the decay of helium plasma, generated in both a dielectric and a metallic container, in a magnetic field at concentratións producing marked diffusion and recombination. In the glass container (pressure equals 0.02 to 1 mm Hg and the magnetic field is less than 25,000 oe at concentrations greater than 10^9 to 10^{10}/cm³), plasma decay loses its exponential character and decay time becomes a function of concentration alone. It was observed that at small plasma concentrations with or without a magnetic field an increase in the temperature intensifies plasma decay. Under magnetic fields of 300 to 1500 oe and at plasma concentrations of 10^{10} to 10^{11}/cm³ the speed of diffusion caused by electron-ion collisions was found to be in accordance with the theory. A study of the effect of the conducting surfaces of the metallic container on plasma decay at helium pressures of $4 \cdot 10^{-2}$ and $8 \cdot 10^{-2}$ mm Hg and with a uniform magnetic field showed that the speed of decay is similar to that in the dielectric container. In the metallic container a decrease in decay time as compared with that of the dielectric container was observed in the region of large magnetic fields. The effect of conducting container walls increased with a decrease in pressure and in the effective length of longitudinal diffusion. It was noted that the change observed in plasma decay time in the metallic container is associated with the equalization of the potential at the plasma boundary.

9) Imyanitov, I. M., G. D. Gdalevich, and Ya. M. Shvarts. Measurement of electrostatic field intensity near the surface of a geophysical rocket. IN: Akademiya nauk SSSR. Doklady, v. 148, no. 6, 1963, 1306-1308.

The electrostatic field intensity near the surface of a geophysical rocket launched 15 November 1961 was measured by means of an electrostatic fluxmeter. The equipment measurement range was ± 6 v/cm. The readings of two symmetrically-placed fluxmeter pickups, although differing from each other, showed that field intensity undergoes relatively slight variations with altitude. The intensity value measured by one of the pickups varied within the range of 0.5 to 1 v/cm, and that of the other from 1.8 to 2.5 v/cm. The second pickup was illuminated by the sun at an angle of 4° throughout the flight, while the first remained in the shade. The electric field intensity corresponding to the charge on the rocket itself had an average value of 1.5 v/cm. After taking into account measurement errors and inaccuracies in the determination of the real value of intensity the average value of the electrostatic field produced by the charge of the rocket was found to be less than 2 but greater than 1 v/cm, i.e., the rocket had a negative charge. Measurements of electron concentration, together with data on field intensity, made it possible to determine that the potential produced by the rocket's own charge amounted to several volts. At an altitude of 200 to 300 km, it was determined that the electric field was less than 3.6 but greater than 1.6 v/cm according to the second pickup, and less than 1.2 but greater than 0.1 v/cm according to the first pickup. It was concluded that during the experiment an electric field intensity of the order of 10^{-3} v/cm existed in the ionosphere.

10) Kovner, M. S., and V. Yu. Trakhtengerts. The interaction between weak corpuscular strear and the upper atmosphere. Geomagnetizm i aeronomiya, v. 2, no. 6, Nov-Dec 1962, 1053-1060.

Certain aspects of generation by weak corpuscular streams of ultralow frequency in the upper atmosphere have been investigated. The mechanism of generation under the influence of Cherenkov magnetic-bremsstrahlung and transient radiation are considered analytically. In the frequency range of $4 \cdot 10^2 \leqslant f \leqslant 3 \cdot 10^4$ cps it is shown that if the refractive index $n \gg 1$, Cherenkov as well as magnetic-bremsstrahlung radiation frequency approaches the frequency $\omega_H \cos\alpha$, where α is the angle between the direction of the magnetic field and the curve vector and ω_H is the gyro frequency. The generation region altitude was found to be between 3r and 5r, where r is the radius of the earth. The existence of radiation of noncoherent origin is explained theoretically. It was found that noncoherent radiation can be observed only if it is generated by streams with an initial velocity of $1.75 \cdot 10^8$ cm/sec. As the stream moves toward the increasing magnetic field of the earth first low and then high frequencies are generated.

11) Lysenko, I. A. Air currents in the meteor zone according to radar observations. Astronomicheskiy zhurnal, v. 40, no. 1, Jan-Feb 1963, 161-170.

To evaluate wind movements in the meteor zone radar equipment for the observation of meteors was designed and regular measurements of the velocity of meteor trail drift were carried out by a pulse-coherent method at the Khar'kov Polytechnic Institute imeni V. I. Lenin between April 1960 and March 1961. The parameters of the equipment were as follows: frequency, 36.9 Mc; transmitter power, 75 kw; pulse repetition frequency, 500 cps; pulse duration, 10 μsec; and receiver sensitivity, 3 to 4 μv. Two five-element Yagi antennas were used separately for reception and transmission purposes. The beamwidth was 35° at the -db level in the horizontal plane. Measurements of wind velocity in east-west and north-south directions were carried out continuously during the last ten days of each month. Radical components of the drift velocities of meteor trails were determined by Doppler frequency shifts based on photorecordings. The winds in the meteor zone proved to be essentially horizontal. Altitude determination based on echo data from meteor trails was accurate to ± 4 or 5 km; the mean altitude of the meteor zone was taken to be 95 km. Mean error of any single drift-velocity measurements amounted to ± 30%. From fifty to several hundred such measurements were made per hour, from which a mean velocity could be assigned to each hour of the daily cycle. Hourly average wind velocity values were then subjected to harmonic analysis, which revealed a constant component plus daily, twice-daily, and 8-hour sinusoidal components, i.e., a fundamental, a 2nd, and a 3rd harmonic. Constant velocities were 30 to 35 m/sec, while those of the daily and twice-daily components were 1 to 12 and 9 to 38 m/sec, respectively. Monthly and seasonal behavior of the various velocity components are presented vectorially in compass coordinates in regard to velocity and direction. A correlation of wind velocity with altitude was found, with a positive gradient of 1 to 1.5 m/sec per km in the 85 to 105 km region. In general, the results agreed well with existing theoretical and experimental work on the subject.

12) Shchepkin, L. A. On the latitude-dependence of the conditions for the appearance of the F_1 layer. Geomagnetizm i aeronomiya, v. 3, no. 1, 1963, 173-174

Analysis of observational data obtained by 40 ionospheric stations in January, March, and June of 1958 has indicated clearly that the probability of an F_1 - layer appearance increases with latitude. This shows that conditions for the division of the nocturnal F layer into two daytime layers (F_1 and F_2) are more

favorable in high latitudes than in low. The probability of an F_1-layer appearance at small values of $\cos\chi$, where χ is the zenith distance of the sun, was studied on the basis of data obtained in 1958 from 29 stations in the northern hemisphere between latitudes of 9 and 80°. The results show that at the same values of $\cos\chi$ the probability of an F_1-layer appearance is greater at high latitudes. This supports the findings of 10 Canadian stations in April and July 1957.

13) Shmelovskiy, K. Kh., L. Klinker, and K. Knuth. Concentration of electrons in the external ionosphere according to observations made of the third Soviet satellite. Geomagnetizm i aeronomiya, v. 3, no. 1, 1963, 25-36.

At the observatory of the Ionospheric Meteorological and Hydrological Service of the German Democratic Republic at Kuhlungsborn regular recordings of 20-Mc signals of the 1958 satellite were made from May 1958 to May 1959. The data obtained were subjected to statistical processing in order to find variations in electron concentration N_n in a vertical column with a transverse cross section of 1 m^2 and a height equal to that of the satellite trajectory. Principal attention was given to the analysis of signal fadings caused by the Faraday effect. The data-processing method was based on measurements of the number of half-turns of the polarization vector. This number is about equal to the minimum number of fadings counted off from the beginning or end of signal recording, depending on whether the number of the polarization vector rotations increases or dimininishes during the satellite flight. The 24-hr period values of N_n were established from recordings averaged over 1-, 2-, and 4-hr periods. Values of N_n for an average height of about 1000 km were as follows: Midnight values varied from $1.8 \cdot 10^{17}$ to $2.0 \cdot 10^{17}$ m^{-2}, independently of season. Noon values varied by season from 6.1·10 in the winter to $3.7 \cdot 10^{17}$ m^{-2} in the summer of 1958 and to $4.4 \cdot 10^{17}$ in the summer of 1959. This difference apparently accounts for changes in average satellite heights. Variations of the general number of electrons at heights of about 400 km were much smaller, i.e., midnight values were 1.[illegible]$\cdot 10^{17}$ m^{-2}, and noon values varied from 2.0 to $2.5 \cdot 10^{17}$ m^{-2}. Irregular variations in the value of N_n at the time of geomagnetic disturbances were analyzed for several cases and the results obtained demonstrate reductions in N_n ranging from 50 to [illegible]0% of its average value. The returns to previous values are very rapid upon the termination of disturbances. An evaluation of reliability of the measurements and of the method of processing was made by comparing data obtained simultaneously in Kuhlungsborn and Prague. The error in determining N_n did not exceed 5%.

14) Yakovleva, G. D., O. I. Yakovlev, and A. I. Rogashkova. The Doppler effect during motion through the inhomogeneities of the medium. Radiotekhnika i elektronika, v. 8, no. 3, Mar 1963, 416-424.

Methods of analyzing Doppler effects during the motion of a receiver through inhomogeneities of the medium are developed for the case in which the variation of the dielectric constant ε in the inhomogeneity is slight as compared with the dielectric constant of the surrounding space. In order to establish a connection between inhomogeneity structure and frequency variation expressions are derived for Doppler-frequency variation during the motion of the receiver within spherically- and cylindrically-shaped inhomogeneities subject to sudden variations in ε. These expressions demonstrate that when the receiver approaches either type of inhomogeneity there is an increase in Doppler-frequency oscillation, its maximum being shifted in relation to the inhomogeneity center. After passage through the inhomogeneity oscillation amplitude and frequency tend toward zero. The main difference between a medium with an inhomogeneity and one with a smoothly changing value of ε in their influence on the Doppler effect is that in the latter instance the frequency shift occurs without variation in the signal spectrum, while in the former the occurrence of a slight shift will be accompanied by a broadening of the signal spectrum. A study of the influence on the Doppler effect of large, arbitrarily shaped, statistically nonhomogeneous media characterized by the Gaussian autocorrelation function leads to the conclusion that in this case the mean square value of Doppler-frequency variation is proportional to the length of the wave path and to the mean square value of $(\Delta\varepsilon/\varepsilon_0)$, and also that the correlation radius of Doppler-frequency variation exceeds by a factor of a/λ the average size of the inhomogeneity, where a is the radius of the cylinder or the sphere.

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TOPIC V. RADIO ASTRONOMY

15) Bazelyan, L. L., S. Ya. Braude, Yu. M. Bruk, I. M. Zhuk, A. V. Men', B. A. Ryabov, L. G. Sodin, and M. K. Shirkin. Measurements of cosmic radiation discrete sources at frequencies below 40 Mc. IN: Akademiya nauk UkrSSR. Dopovidi, no. 2, 1963, 188-192.

The Institute of Radiophysics and Electronics of the Ukrainian Academy of Sciences measured the absolute and relative radiation intensities of Cassiopeia A, Cygnus A, Taurus A, and Virgo A sources in the 12–40-Mc range during June-November 1961 and March-June 1962. Two types of instruments were used: 1) An interferometer for the 12–20-Mc range consisting of two wideband dipole arrays with centers mounted 332 m apart in an east-west direction. Each array had 24 dipoles 7.8 mm in length. The radiation patterns were 30° wide at half-power points at 12 Mc and 20° wide at 17 Mc in a north-south direction. The widths of the interference pattern in an east-west direction were 4.5 and 3.2° for the same frequencies. The arrays were connected through a summation unit to a modulation-type radiometer with a bandwidth of 5 kc. One of the arrays fed a phase modulator (50-400 cps) which provided for either an in-phase or out-of-phase connection of antennas. 2) A meridian-type telescope for the 20–40-Mc range which consists of a multidipole rectangular array (16.5 x 172 m) having 128 horizontal dipoles (4.75 m in length) and oriented in an east-west direction. The radiation patterns were 4.6° wide at half-power points at 20 Mc and 2.3° at 40 Mc in an east-west direction. The antenna output was connected to a compensating-type radiometer with a bandwidth of 5 kc. Results show that in general the radiation intensity increases with an increase in frequency. For the Cassiopeia A source, for example, an increase in frequency from 12.4 to 30 Mc is associated with an increase in intensity from 340×10^{-24} to 650×10^{-24} w/m²·cps. The errors were about 13-25% for upper experimental frequencies and were as great as 45% for lower frequencies.

16) Bibinova, V. P., A. D. Kuz'min, A. Ye. Salomonovich, and I. V. Shavlovskiy. Observations of radio emissions of Venus and Jupiter at the 3.3-cm wavelength. Astronomicheskiy zhurnal, v. 39, no. 6, Dec 1962, 1083-1088.

Observations of radio emissions of Venus and Jupiter were carried out at the 3.3-cm wavelength in 1961 at the Physics Institute imeni P. N. Lebedev, Academy of Sciences USSR with

a 22-m radio telescope. A modulation radiometer with a sensitivity of 0.1°K at a time constant of 16 sec was used as a receiver. Measurements of antenna temperature were made by comparing the observed signal with a standard signal of known intensity from a gas-discharge noise generator. The Venus observations were made from May 26 to July 10, during which period the relative area of the illuminated part of the visible disk varied between 0.33 and 0.6. The mean brightness temperature of Venus averaged over the disk was 542°K (±85°K). The brightness temperature showed a tendency to increase with the area of the illuminated part of the visible disk, which demonstrates a difference in temperature of the night and day sides of the planet. Radio emissions of Jupiter were observed on four nights between July 1 and 10. The brightness temperature did not remain constant from day to day, averaging 193°K.

17) Grigor'yants, V. V., and I. N. Orayevskiy. Compensation method for measuring the efficiency of molecular beam utilization. Radiotekhnika i elektronika, v. 7, no. 12, Dec 1962, 2088-2089.

In an effort to improve the operational characteristics of molecular generators a method of measuring the efficiency of a molecular beam by means of an ammonia molecular generator has been developed. The essential parts of the generator are a beam source, a focusing element, and a resonator sink, all encased in an evacuated chamber. Pressures are measured by means of a thermocouple in the source and a gauge in the resonator. The ammonia tank is valved to supply the beam source through a flowmeter and can be switched to feed ammonia through the rear wall of the resonator. Once the desired pressure is established in the beam source the corresponding flow rate is measured (N_{tot} = mol/sec). The portion of the beam molecules which appears in the resonator creates a pressure which is recorded. The amount of this flow is found by first evacuating the entire system and then feeding ammonia through the rear wall of the resonator until the previously recorded pressure is reached; the flow which yields the pressure is N_{beam}. Thus, beam efficieny N_{beam}/N_{tot} can be evaluated. Since the absolute pressure in the resonator is negligible, its gauge has little evacuating effect. The measurement error is estimated at 12%, which is said to be better than that attainable with current techniques.

18) Korol'kov, D. V., Yu. N. Pariyskiy, G. M. Timofeyeva, and S. E. Khaykin. High resolution radioastronomical observations of Venus. IN: Akademiya nauk SSSR. Doklady, v. 149, no. 1, Mar 1963, 65-67.

During the period October-November 1962 observations of radio emission from Venus were carried out on the 3.02-cm wavelength at the Main Astronomical Observatory of the Academy of Sciences USSR by means of the large Pulkovo radio telescope. An antenna with variable cross section was used which acted as a filter of space frequencies and made it possible to investigate all surface frequencies up to $\omega = 3500$. In order to increase the signal-to-noise ratio a radiometer using a single-stage parametric amplifier of ~ 200 Mc was developed at the Observatory. The noise temperature of the radiometer together with the antenna was ~ 500°K, while sensitivity was ~ 0.07°K at a time constant of 1.6 sec. The width of the pattern was found to be 1.20' ± 0.03' at half-power points and 3.1' ± 0.04' at the -20-db level. The following conclusions were derived from the study: 1) The radio emission flow from the region of a radius R♀ = 6.R does not exceed 3% of the emission connected with the visible disk of the planet. 2) At a distance of 1.07 R♀ from the center of the planet radio emission is virtually nonexistent, i.e., the altitude of the radio-emission region has its maximum 420 km above the cloudy cover of Venus. 3) An identical widening of the radiation pattern is yielded by the Gaussian curve and the real brightness distribution. 4) Under the assumption that the average temperature of the nonilluminated part of the disk is 570°K the amplitude of the variable component of the brightness temperature does not exceed 170°K.

19) Kotel'nikov, V. A., L. V. Apraksin, V. O. Voytov, M. G. Golubtsov, V. M. Dubrovin, N. M. Zaytsev, Ye. B. Korenberg, V. P. Minashin, V. A. Morozov, N. I. Nikitskiy, G. M. Petrov, O. N. Rzhiga, and A. M. Shakhovskoy. Radar system used for Venus probing in 1961. Radiotekhnika i elektronika, v. 7, no. 11, 1962, 1851-1859.

A special radar system for radar examinations of Venus has been developed by the Institute of Radio Engineering and Electronics, Academy of Sciences USSR. The transmitter frequency is approximately 700 Mc and the power flux density is 250 mw/sterad. Polarization is circular for transmission and linear for reception. Transmission frequencies, keying modulation, and local receiver oscillators were crystal controlled to a stability of more than $1{:}10^9$. Frequency corrections were applied during transmission to compensate for the Doppler shift caused by changes in the distance between the Earth and Venus and by the earth's rotation. Carrier modulation was by telegraphic-type pulse trains with pulse

durations of 128 or 64 msec. Transmission was made at five-minute intervals. The return signals were heterodyned to 750 cps and recorded on tape by using a passband of 420 to 1020 cps. A 2-kc signal was recorded simultaneously as a time base. The start of this timing-signal recording, controlled by the master timer, coincided within 1 msec with the calculated arrival time of the reflected signals. This permitted comparison of calculated and actual time of the signal to Venus and back. The taped signals were then analyzed by playback through a bank of filters having a bandwidth of 4 to 60 cps. The presence of the signal was determined by comparing the recorded energy of the receiving interval (signal + noise) to the energy of an equal subsequent interval (noise only). For the transmitter configuration used and for a signal-to-noise ratio equal to 1 at the analyzer output, the power flux density was $5 \cdot 10^{-23}$ w/m^2 with the 60-cps and $1 \cdot 10^{-23}$ w/m^2 with the 4-cps filter.

20) Kotel'nikov, V. A., V. M. Dubrovin, V. A. Morozov, G. M. Petrov, V. N. Rzbiga, Z. G. Trunova, and A. M. Shakhovskoy. Results of Venus radar probing in 1961. Radiotekhnika i elektronika, v. 7, no. 11, 1962, 1860-1872.

Data is given on radar reflections received from the Venus probe in April 1961, the transmitted frequency of which was about 700 Mc. Spectral analyses of the reflected signals show that they include narrow-band and wide-band components. The former component was limited to 4 cps and was nearly constant in amplitude during observations. From the narrow-band reflections, the reflection factor of Venus was calculated to be 0.08 when referenced to the radiation source in Cassiopeia A. The narrow-band data were also used to recalculate the value of the astronomical unit as 149,599,300 km with an rms error of 580 km. The spectrum of the wide-band fluctuating component of the reflected signal extended to at least 400 cps, while its amplitude varied considerably. It is suggested that if the surface of Venus is assumed to be smoother than that of the Moon, the wide-band variations are caused by reflection from the entire illuminated area and by a Doppler shift which is due to the planet's rotation, while the narrow-band reflections come from a small area of the surface nearest the Earth. This hypothesis yields a rotation period of 11 days for Venus if its axis is normal to the Earth-Venus line of sight, less if its axis is inclined. However, if the reflective properties of Venus are the same as the Moon's, then the narrow-band data must be used to account for planet rotation. This calculated period exceeds 100 days.

21) Kotel'nikov, V. A., G. Ya. Gus'kov, V. M. Dubrovin, B. A. Dubinskiy, M. D. Kislik, Ye. B. Korenberg, V. P. Minashin, V. A. Morozov, N. I. Nikitskiy, G. M. Petrov, G. A. Podoprigora, O. N. Rzhiga, A. V. Frantsesson, and A. M. Shakhovskoy. Radar observations of Mercury. IN: Akademiya nauk SSSR. Doklady, v. 147, no. 6, 21 Dec 1962, 1320-1323.

The Institute of Radio Engineering and Electronics, Academy of Sciences USSR, conducted radar observations of the planet Mercury from June 10 to 15, 1962, at a frequency of 700 Mc with the use of a circularly polarized transmitting antenna. The transmitter power was 375 Mw/sterad, with about 1 w reaching the visible surface of Mercury. Each transmission had a duration of about 10 min, during which the signal reached Mercury and returned to Earth. The reflected signals were received with the use of a linearly polarized antenna. The receiver input was equipped with paramagnetic and parametric amplifiers. The astronomical unit was assumed to be 149,599,300 km and the speed of light, 299,792.5 km/sec. Energy distribution in the spectrum of recorded oscillations was studied by means of a 20-channel analyzer having two-mesh filters with a bandwidth of 16 cps (at a level of 3 db), whose midband frequencies differed by 16 cps. Radar sensitivity calibration was based on the radiation of the discrete Cassiopeia A source. Results of 53 transmissions showed that the Mercury reflection factor in the 12 to 20 cps band is 6%, which is close to the data obtained by radar observations of the moon. The results of the observations confirm those obtained for the astronomical unit in 1961 during radar observations of Venus.

22) Krotikov, V. D. Some electrical characteristics of terrestrial rocks and their comparison with the characteristics of the lunar surface layer. Izvestiya vysshikh uchebnykh zavedeniy. Radiofizika, v. 5, no. 6, 1962, 1057-1061.

A comparison of the characteristics of the lunar surface with those of rocks on the earth is made on the basis of the utilization of the ratio $\tan \Delta/\rho$ (where $\tan \Delta$ is the loss tangent and ρ the density), whose value depends mainly on chemical composition. On the basis of lunar radiation data it was found that $\tan \Delta/\rho$ for lunar surface material equals 0.005 ± 0.003. The dependence of $\tan \Delta$ and ε on frequency and density has been determined for various terrestrial rocks, both in their natural and crushed state, by a method which makes it possible to measure ε at the 0.8-, 3.2-, and 10-cm wavelengths with an accuracy of $\pm$ 3 to 7% and $\tan \Delta$ to within $\pm$ 10 to 20%, depending on the wavelength and magnitude of $\tan \Delta$. The measurements, with an accuracy of $\pm$ 5%, have proved that the magnitude

of $(\sqrt{\varepsilon} - 1)/\rho$ varies very little with different rocks. Under the assumption that $(\sqrt{\varepsilon} - 1)/\rho$ is the same for lunar rocks and that $\varepsilon = 1.5 \pm 0.3$ for the lunar surface, the density of the surface of the moon is $0.2 \leqslant \rho \leqslant 0.7$. This value is in agreement with density values obtained from other data.

23) Krotikov, V. D., and V. S. Troitskiy. Radiation properties of the Moon at centimeter wavelengths. Astronomicheskiy zhurnal, v. 39, no. 6, Nov-Dec 1962, 1089-1093.

Precise measurements of lunar radio temperature at the 3.2-cm wavelength averaged over the disk gave a value of 210°K($\pm$ 5°) for the constant component. Since the radiation of an absolute black moon at the most probable values of night and day surface temperature (125 and 391°K) as calculated by the temperature distribution equation $\eta(\psi) = (\cos)^{1/2}\psi$, ψ being the lunar latitude, yields a temperature of 218°K, it follows that at $\lambda = 3.2$ cm the surface of the moon is almost absolutely black. This can be true in two extreme cases: 1) if hard lunar rock for the 3.2-cm wavelength is very uneven or 2) if the surface is sufficiently smooth and the rock consists of very porous light material. There is reason to believe that the lunar surface is so smooth that at the 3.2-cm wavelength Fresnel's reflection formulas still hold. From experimental data it follows that 1) the reflection factor of radio emission from the lunar surface at centimeter wavelengths is less than 0.02 at perpendicular incidence, 2) the dielectric constant of the surface material is $1.1 \leqslant \varepsilon \leqslant 1.7$, and 3) its density is $0.2 \leqslant \rho \leqslant 0.89$ g/cm. These values are in good agreement with earlier published data.

24) Krotikov, V. D., and V. S. Troitskiy. The thermal conductivity of lunar rock according to data of lunar radio-emission precision measurements. Astronomicheskiy zhurnal, v. 40, no. 1, Jan-Feb 1962, 158-160.

The thermal parameter $\gamma = (K\rho C)^{-1/2}$, in which K is the coefficient of thermal conductivity, ρ is volumetric density, and C is thermal capacity, has been recalculated on the basis of recent lunar emission data, resulting in a new value of K for the lunar surface. Three independent methods were used to obtain γ, based on emission temperature data during the lunar day and night and including some infrared return. The three ranges of γ found in this manner were 250-450, 250-550, and 300-440, from which a value of 350 ± 75 was considered as correct. With $\gamma = 350$, $C = 0.2$, and $\rho = 0.5$ gm/cm^3 (the lunar surface density found earlier by the same authors), the thermal conductivity K is found to be $(1 \pm 0.5)\cdot 10^{-4}$ cal/cm/sec/deg, which exceeds the generally accepted value by

some 50 times. The new value of K rules out a dust surface for the moon and suggests instead porous rock, possibly somewhat pulverized. This study was carried out at the Radiophysics Institute of Gor'kiy State University imeni N. I. Lobachevskiy.

25) Kuz'min, A. D., and A. Ye. Salomonovich. The direction and period of Venus' rotation determined on the basis of radio-astronomic data. Astronomicheskiy zhurnal, v. 40, no. 1, Jan-Feb 1963, 154-157.

A method is described for determining the period and direction of Venus' rotation from short-term variations in the brightness and temperature of the disk as distinguished from long-term (synodic) variations. The data used consisted of existing records of 8- and 3.3-cm emission from Venus during a 110-day period. To establish a statistical correlation of temperature variations, the time relationship was assumed to be the sum of a periodic function with period T, for which the autocorrelation coefficient $R(\tau)$ would be maximum for $\tau = nT$ ($N = 1, 2, 3, \ldots$). From recorded data, $R(\tau)$ had a maximum of 0.75 for $\tau = 72$ days, which was thus taken to be the synodic rotation period for Venus; correction for Earth's motion then gave 69 days as the true rotational period. From this it is shown that on Venus one day is approximately equal to 100 Earth days. In determining the rotational direction it was noted that from Earth the apparent synodic motion of Venus would decrease at inferior conjunction and increase elsewhere if the planet had a positive rotation. If, however, the motion were retrograde, the reverse would be true. The temperature observations agreed with the former case, indicating positive rotation. The discontinuous nature of returns over the area of the disk of Venus suggests the existence of continents and oceans. It is suggested that the possibility for error in the method described is great, so results must be verified by further data. This study was carried out at the Physics Institute imeni P. N. Lebedev, Academy of Sciences USSR.

26) Salomonovich, A. Ye., and B. Ya. Losovskiy. Observations of the distribution of radio brightness along the lunar disk at the 0.8-cm wavelength. Astronomicheskiy zhurnal, v. 39, no. 6, Nov-Dec 1962, 1074-1082.

Observations of lunar radio brightness were made between September and December 1959 at the Physics Institute imeni P. N. Lebedev, Academy of Science USSR, with a 22-meter radio telescope. More than 50 recordings were processed to determine brightness temperature T at the center of the lunar disk. The method of least squares was used for determining

variations in T with change in the phase of the moon. It was found that the temperature can be approximated by the formula $T = 211^\circ - 40^\circ \cos(\varphi - 30^\circ) + 14^\circ \cos(2\varphi - 22^\circ)$. The accuracy of absolute and relative measurements was ± 15 and $\pm 5\%$, respectively. The recordings of radio brightness distribution along the equator and the central meridian permitted determination of the law of variation of radiation for an effective dielectric constant < 2. The distribution of heating on the lunar surface as a function of latitude ψ was determined as approximately $\cos^{1/2}(\psi)$. The ratio of the penetration depths of the radio wave and the first harmonic of the thermal wave was found to be 2. The phase lag of variations of the first harmonic of T is in good agreement with the observational one and argues for the validity of the one-layer model.

27) Soboleva, N. S. Measurements of the polarization of lunar radio emission at the 3.2-cm wavelength by means of the large Pulkovo radio telescope. Astronomicheskiy zhurnal, v. 39, no. 6, Nov-Dec 1962, 1124-1126.

In August 1961, linear polarization of lunar radio emission was detected at the 3.2-cm wavelength by the Radio Astronomy Section of the Main Astronomical Observatory of the Academy of Sciences USSR, using the large Pulkovo radio telescope with a direct amplification receiver equipped with three traveling-wave tubes. The radiation pattern was $1' \times 40'$ and the elevation was 10°. The percentage of polarization was found to depend only on the value of the dielectric constant and on the angle between the direction of the normal to the surface and the direction toward the observer. Polarization curves which take into account the roughness of the lunar surface show that the best agreement with experimental data occurs when ε is equal to 1.65, the angle of radiation scattering equals 40°, and the lunar temperature distribution follows the equation $\eta^2 = \cos\psi$, where ψ is the lunar latitude.

28) Soboleva, N. S., V. A. Prozorov, and Yu. N. Pariyskiy. Distribution of polarized and nonpolarized radio emission in the Crab Nebula. Astronomicheskiy zhurnal, v. 40, no. 1, Jan-Feb 1963, 3-11.

Observations of the radio brightness distribution of the Crab Nebula were carried out at the Main Astronomical Observatory, Academy of Sciences USSR. An antenna with a variable dish operating at wavelengths of 3.2 and 8.7 cm was used. The width of the directional pattern at half-power points and an elevation of 52° was $1' \times 6.5'$ at 3.2 cm and $2.9' \times 18'$ at 8.7 cm. The utilization factor of the effective antenna surface was about 0.45 at 8.7 cm and

about 0.3 at 3.2 cm. Wide-band straight-amplification radiometers using three TW tubes were used. Radiometer sensitivity was about 0.2°K with an integrator time constant of 2.7 sec. A detailed comparison of radio emission distribution with that of continuous optical emission shows that the region of radio emission is larger than that of the optical. This can be explained either by the presence of a strong peripheral magnetic field or by an increase in the spectral index toward the periphery of the nebula. The polarization distribution and the elevations of the nebula polarization plane at 3.2 cm were obtained. The region with strong linear polarization of radio emission is considerably smaller than the radio source as a whole. In the central part of the nebula the polarization at 3.2 cm is 17.5% and practically equals that of optical emission. The elevation of the polarization plane in the central part is 145°, differing from that of optical measurements by 10° to 13°. The character of variations of the elevation at 3.2 cm is similar to that observed in the optical range.

29) Troitskiy, V. A. A new discovery of the radioastronomers. Temperature of the lunar interior. Turkmenskaya iskra, 16 Jan 1963, 4, cols. 1-3.

The existence of a hot lunar interior has been experimentally verified by measurements of the intensity of radio emission from the Moon at wavelengths of up to 50 cm. The temperature of lunar rocks at depths of 15 to 20 m was found to be more than 25° higher than that at the surface. Since measurement errors were negligible, the increase of temperature with wavelength has been attributed to the existence of a hot interior. The density of the lunar internal heat flow is estimated to be about that of the Earth. Under the assumption that, as in the case of the Earth, all the heat of the Moon results from the decay of radioactive elements, the mean concentration of such elements should be five to six times greater than that in the Earth. Radio measurements further indicate that the temperature at depths of 50 to 60 km is about 1000°. The character of the temperature-wavelength growth indicates that the structure of the upper layers of the Moon is homogeneous to a depth of approximately 20 m. Since the density of the matter composing the lunar surface has already been determined to be half that of water, it is believed that the lunar surface layers must be of a porous pumice nature.

30) Udal'tsov, V. A. The polarization of Crab Nebula emission at the 21-cm wavelength. Astronomicheskiy zhurnal, v. 39, no. 5, 1962, 849-855.

Measurements to determine the polarization characteristics of the Crab Nebula at the 21-cm wavelength were made in October and November 1960 at the Crimean Radioastronomical Station of the Physics Institute, Academy of Sciences USSR, with a stationary radio telescope

31 m in diameter. A conical horn was used as the antenna radiator; the antenna bandwidth at the 3-db level was 32'. A correlation method which eliminates the nonpolarized component of the signal and records the polarized component directly was used. A special polarimeter, consisting of a two-channel receiver with a special correlation filter at the output, was designed for the observations. The two channels made possible signal reception in two mutually perpendicular polarization planes. Each channel operated as a conventional receiver; however, they had a common heterodyne oscillator. Splitting for two different polarizations was achieved by a circular waveguide with two circular-to-rectangular joints. The noise factor of each channel did not exceed 5. The heterodyne and intermediate frequencies were 1440 and 60 Mc, respectively. The sensitivity of the polarimeter was approximately 0.3°K at an i-f passband of 4 Mc and an output-filter time constant of 24 sec. The ЭПП-0.9 signal recorder was used. The antenna temperature of nonpolarized radiation was 110°K. Parasitic polarization caused by various equipment effects was evaluated by control measurements on the 9.6-cm wavelength and taken into account in the analysis. It was found that radio emission of the Crab Nebula at 21 cm is linearly polarized with a degree of polarization of $0.5 \pm 0.15\%$ and that the position angle of the plane of polarization is $82 \pm 5°$. That these figures are low in comparison with those obtained in experiments at 10 cm can be explained by the existence of the Faraday effect in the medium along the path of the polarized emission.

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